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ASSESSMENT OF THE DIELECTRIC PROPERTIES OF SOIL AROUND DELTA STATE UNIVERSITY OF SCIENCE AND TECHNOLOGY, OZORO, NIGERIA

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Keywords: *Dielectric Properties, soil, conductivity, Delta state.*

Abstract: *An adequate comprehension of soil electrical properties not only facilitates the design and implementation of electrical and telecommunication systems, but also improves agricultural production. The goal of the research is to determine the dielectric properties of soil within the premises of Delta State University of Science and Technology (DSUST) in Ozoro, Nigeria. Soil samples were collected from nine strategic locations covering an area of 0.5 km² within the school (university) community. The dielectric constant (ε'), dielectric loss (ε''), and relaxation time (τ) levels of the soil samples were assessed following ASTM-approved procedures. The outcomes of the laboratory tests showed that the dielectric constant (ε') of the delineated area varied between 2.9 and 4.6, with the central part of the study area exhibiting the highest ε' values. Likewise, the soil's dielectric loss (ε'') values ranged from 0.8 to 1.15 across the area, with the soil in the central part showing the highest ε'' results. Furthermore, the soil's relaxation time ranged from 3.72 to 4.59, with the northern part of the region displaying a higher relaxation time compared to soil from other locations within the region. The findings of this study have revealed the heterogeneity of soil electrical properties, and the results will provide valuable insights into several agricultural and electrical engineering applications.*

1.0 Introduction

Soil electrical properties are some of the fundamental properties of the soil, and play a crucial role in various soil processes and functions. These properties include electrical conductivity (EC), dielectric permittivity (ε), soil resistivity and chargeability, and they are dependent on the moisture content, mineral composition, and organic matter content of the soil (Gustavo Fano, 2019). Through technological advancement, the soils electric properties are widely applied in the telecommunications, electrical engineering, geophysics, and agricultural sectors (Pradipta *et al.,* 2022). Soil electrical behaviors play a crucial role in facilitating the propagation of electromagnetic waves within the soil mass. As such, they are given significant consideration during the design and implementation of wireless communication systems.

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In electrical installations, the electrical properties of the soil play a significant role in the design of electrical earthing systems. Some of the soil properties that significantly affect the performance of the electrical grounding systems are: soil EC, moisture content, resistivity texture and structure (Edeko and Omorogiuwa, 2022). The soil texture and structure influences the soil moisture and permeability levels of the soil, which subsequently influence soil electrical conductivity and resistivity. Fine grained particles soils (clay soils) tend to retain high volume of water, and possess lower soil permeability compared to coarse-grained soils like sandy soils. As a result, clay soils generally exhibit lower electrical resistivity but higher electrical conductivity compared to sandy soils (Long *et al.,* 2012). Adequate information on soil dielectric parameters is essential for minimizing capacitive coupling and other electrical effects, which may arise due to the interaction between electric fields generated by cables and the surrounding soil. This will ensure the adequate insulation procedures and safety measures, to be implemented during designs of telecommunication and electrical systems (Chanzy *et al.,* 2012; Li *et al*., 2023).

Soil dielectric constant values are highly dependent on the soil texture and moisture content, factors that are directly associated with quantity of organic material present in the soil. Soils with a high percentage of organic content typically exhibit finer texture, higher moisture content, lower resistivity, and higher dielectric constant (Martini *et al*., 2017). Soil organic materials usually have greater dielectric constants compared to soil inorganic materials. This behavior is essential during the installation of electrical and telecommunication systems (Sahu et al., 2018). Adequate information on the soil dielectric parameters is crucial during the design of telecommunication systems. These dielectric parameters facilitate the proper propagation and distribution of electromagnetic waves and electric fields in underground telecommunication infrastructures (Banaseka *et al*., 2021).

In the agricultural engineering sector, soil electrical properties are valuable indicators used for various purposes such as: evaluating groundwater table depth, assessing water quality, and estimating soil electrical resistivity (Gustavo Fano, 2020). The electrical properties of the soil can indirectly provide insights the soil fertility status, crop growth and crop yield. This could aids prediction of the soil fertility and crops performances, through their incorporation into predictive models and decision support systems (Corwin and Lesch, 2003; Sui, 2019). Several researches had been done on the dielectric properties of agricultural soils (Navar khele *et al.,* 2009; Chaudhari, 2015; Syeda et al., 2020; Muhammad et al., 2022; Khan *et al*., 2023), and their results have highlighted the significant influence of soil physiochemical and mechanical properties on these electrical characteristics. Though numerous works have been done on the in-situ soil dielectric properties, related literature search revealed little information on the dielectric behavior of soils located in Ozoro community of Delta State Nigeria. Therefore, the main goal of this research is to investigate the dielectric properties of soil located within the premises of Delta State University of Science and Technology (DSUST), Ozoro, Nigeria. The results obtained from this study will be helpful in the design of electrical installations with the university community.

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2.0 Materials and Methods

2.1Study Area

The study was carried within the premises of Delta State University of Science and Technology, Ozoro, Nigeria. The area under investigation was the research center of the department of agricultural engineering, DSUST, and has a land mass of about 0.5 km^2. The research center has high water table during the rainy season, and prone to seasonal flooding. The school community is located in the tropical rain forest region of Nigeria, having to major climatic seasons – rainy (wet) and dry seasons, with cumulative rainfall volume of about 1,800 mm per annual (Uguru *et al*., 2022).

2.2 Sample collection and preparation

The soil samples were collected from nine strategic locations within the research area, at a soil depth of 0.4 m by using a soil auger. All the samples were coded accordingly and taken to the laboratory for further processing. In the laboratory, the soil samples were air dried under ambient room environmental conditions (temperature – 30±5^{o}C, relative humidity – 80±10%). The soil sampling was done April, 2022, at the beginning of the rainy season.

2.3 Laboratory analysis

Dielectric constant and loss

The soil samples dielectric constant (ε′) and dielectric loss (ε″) were measured in harmony with ASTM D150 procedures, at a microwave frequency of 7.0 GHz (ASTM D150, 2018). After each testing the ε′ values of each soil specimen was computed by using the expression in Equation 1.

$$\text{Dielectric constant} = \frac{C_a}{C_v} \quad (1)$$

Where = C_a and C_b are the soil specimen capacitance and free air capacitance, respectively.

Relaxation time

The relaxation time (τ) was calculated through Equation 2.

$$\tau = \frac{\varepsilon''}{\omega\varepsilon'} \quad (2)$$

Where ω = 2πf

3.0 Results and Discussion

3.1 Dielectric constant

The results of the dielectric constant of the soil sampled from the region are presented in Figure 1: Figure 1 indicated that the dielectric constant of the area ranged from 2.9 to 4.6, with the central part of the research station (studied area) having the higher dielectric constant, when compared to the southern and northern parts of the research station. The higher dielectric constant recorded at the middle of the study region (Points D, E and F) could be attributed to the higher organic content of the sub-region, resulting from agricultural activities that added humus to the soil. This addition of humus-rich organic material can influence the dielectric properties of the soil (Zhao *et al*., 2023). Similarly, Harish (2023) stated that humus, which is the organic component of soil formed by the decomposition of agricultural materials, tends to have a higher dielectric properties compared to mineral soils; hence, it presence increased the ε′ of the soil to a considerable level.

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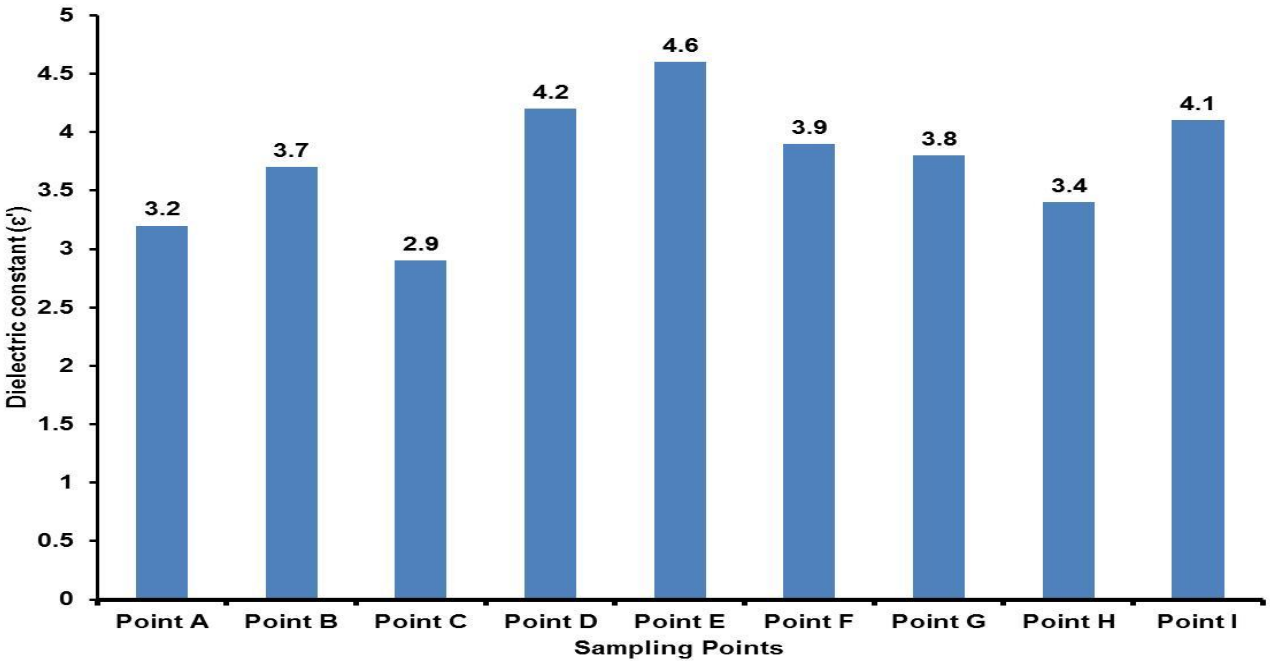

Figure 1: Dielectric constant of the soil specimens

3.2 Dielectric loss

Figure 2 presents the dielectric loss (ε″) results of the various soils sampled from the study region. It was observed from the results that the soil ε″ values ranged from 0.8 to 1.15 across the research station, with the soil samples collected from the central part of the area recorded the highest dielectric loss results. The lower results obtained in the northern parts (Points A, B and C) can be linked to poor organic maters content in this sub-region's soil. The specific characteristics of soil and their dielectric properties vary widely depending on factors such as soil type, land use, and environmental conditions (Tsolis and Barouchas, 2023). The dielectric loss of soil is greatly influenced by the volume and composition of both inorganic and organic materials present in the soil. Soil with higher inorganic solute tends to have lower dielectric loss when compared with soil with organic solute/solution. According to the report of Chaudhari *et al.* (2013), soil with a higher content of organic solutes or solutions, such as those resulting from decomposition of organic matter, may experience higher dielectric losses due to the increased presence of polar molecules that can absorb and dissipate electrical energy. Soils with very high dielectric loss tend to have negative impact of the performance of electrical and electronic components and devices, which can be linked to the high energy lost to the environment (Yuan *et al.*, 2023).

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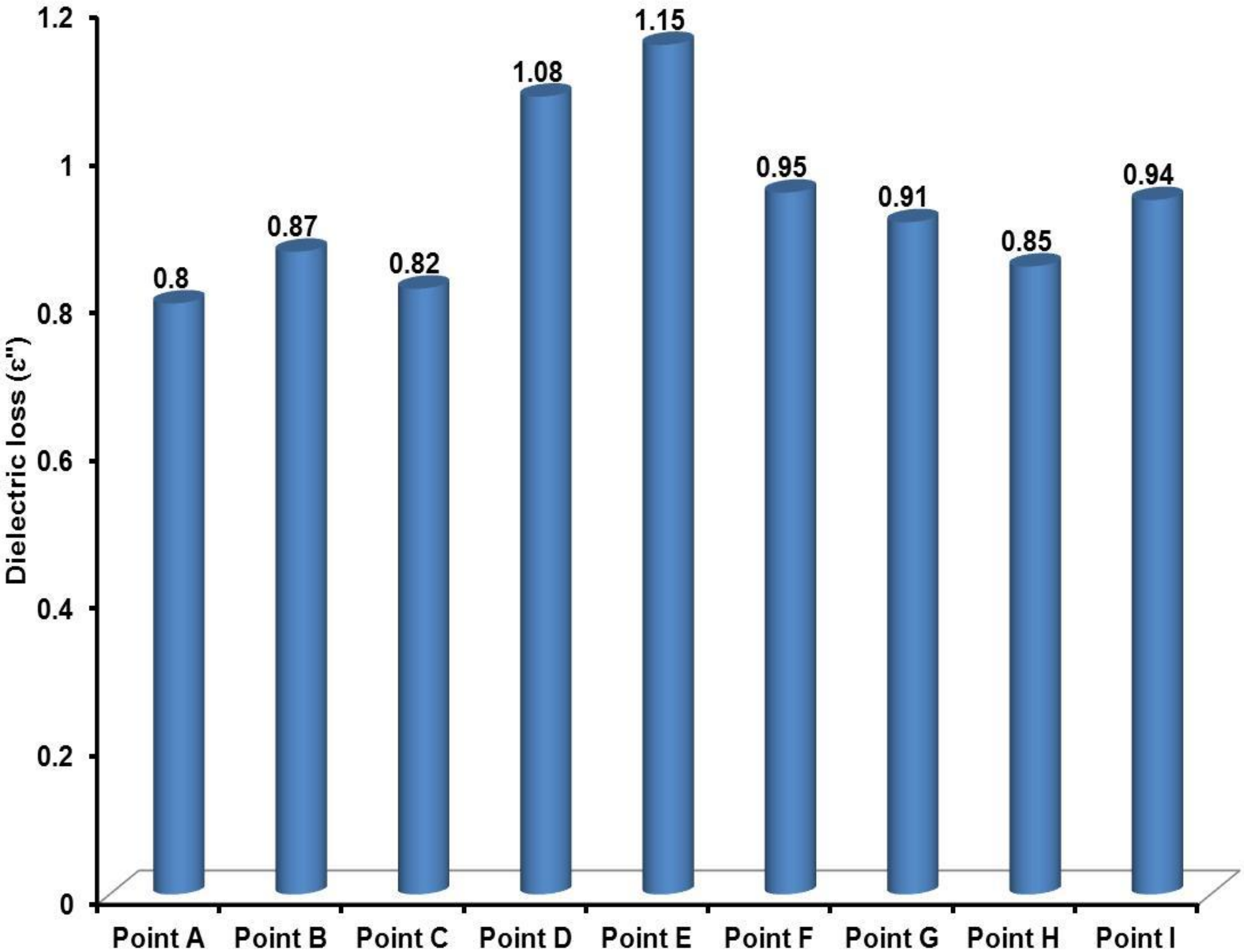

Figure 2: The dielectric loss of the soil samples

3.3 Relaxation time

Figure 3 displays the outcomes derived from the relaxation time analysis of the soil samples. The relaxation time of soil samples collected from the study area varied between 3.72 and 4.59. Soil from the northern part of the region exhibited a higher relaxation time compared to soil from other locations within the region. This difference could be attributed to variations in soil composition, moisture content, or other factors that affect the dielectric relaxation behavior of the soil. Syeda *et al.* (2020) stated that relaxation time is the time taken for the dipoles in a soil to return to their equilibrium state after being perturbed by an external electric field; and it is dependent on the organic matter content, moisture content, mineral composition and temperature of the soil.

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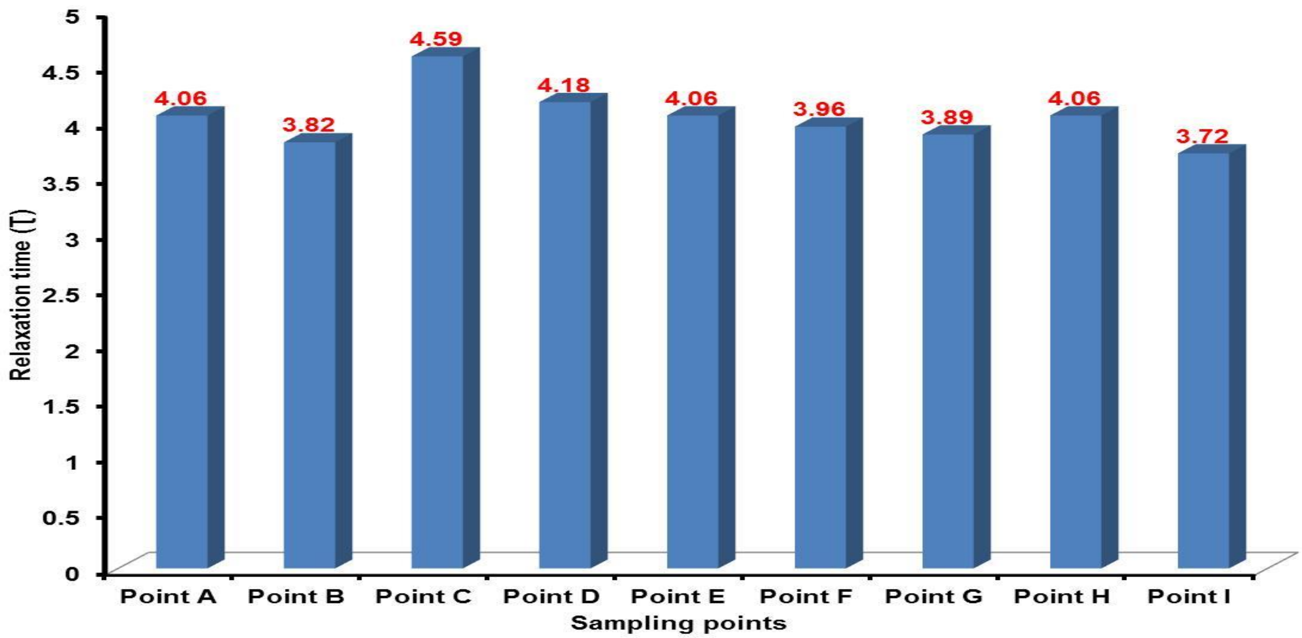

Figure 3: The soil samples relaxation time

4.0 Conclusion

This study was conducted to assess the dielectric properties of alluvial soils located within the Delta state of Nigeria. Nine soil samples were collected from the DSUST Ozoro campus, and their dielectric constant, dielectric loss, and relaxation time were determined following the guidelines outlined by ASTM. The results obtained from the laboratory testing indicated that the values of soil's ε', ε'', and τ are significantly influenced by the sampling location. In particular, the soil in the central region of the study area exhibited the highest values for ε' and ε'', while concurrently displaying the lowest values for relaxation time. These results have affirmed the heterogeneity of soil electrical properties, offering valuable insights applicable to various agricultural and electrical engineering contexts.

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